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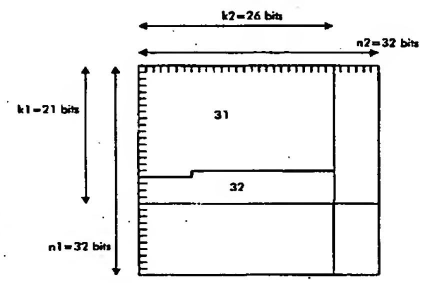
(54) METHODE DE CODAGE DE CELLULE AU MOYEN D'UN CODE DE PRODUIT, POUR UNE APPLICATION A SATELLITE

(54) A METHOD OF ENCODING A CELL BY A PRODUCT CODE, FOR A SATELLITE APPLICATION

(57) The invention relates to a method of encoding a short cell by means of a product code enabling a good compromise to be obtained between the transmitter power and the bandwidth required in the context of satellite transmission. According to the invention, the row code and the column code making up the product code are both binary linear block codes selected in such a manner that one of them has the capacity to correct one error and the other has the capacity to correct two errors.



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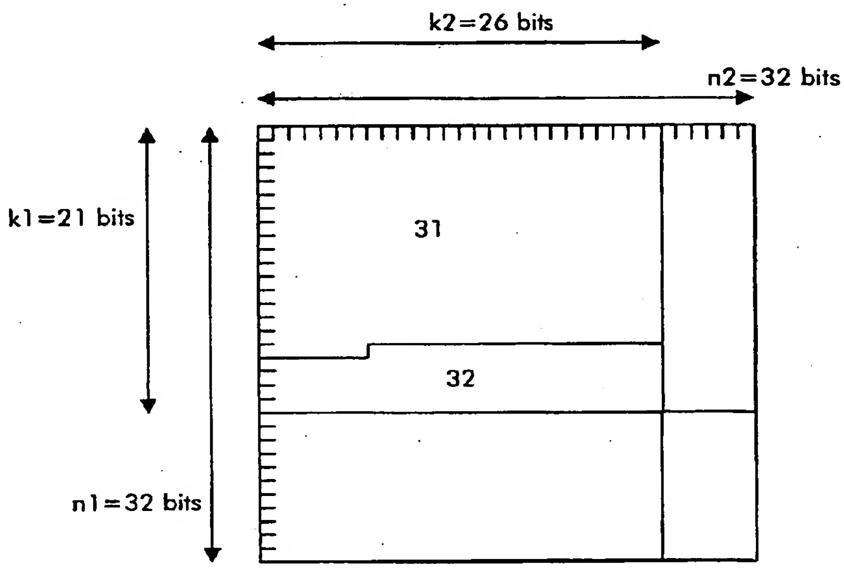
(54) **A METHOD OF ENCODING A CELL BY A PRODUCT CODE, FOR A SATELLITE APPLICATION**



(57) The invention relates to a method of encoding a short cell by means of a product code enabling a good compromise to be obtained between the transmitter power and the bandwidth required in the context of satellite transmission. According to the invention, the row code and the column code making up the product code are both binary linear block codes selected in such a manner that one of them has the capacity to correct one error and the other has the capacity to correct two errors.

A B S T R A C T

The invention relates to a method of encoding a short cell by means of a product code enabling a good compromise to be obtained between the transmitter power and the bandwidth required in the context of satellite transmission. According to the invention, the row code and the column code making up the product code are both binary linear block codes selected in such a manner that one of them has the capacity to correct one error and the other has the capacity to correct two errors.

A METHOD OF ENCODING A CELL BY A PRODUCT CODE, FOR A SATELLITE APPLICATION

The field of the invention is that of encoding data. More precisely, the present invention relates to a method enabling data blocks to be encoded by means of a product code using special families of row codes and column codes. The invention applies in particular to encoding ATM cells.

Product code encoding is a known form of encoding that serves to encode data that is to be transmitted, e.g. by radio. Figures 1 and 2 show the principle of product encoding.

We consider here a block of 90 data bits to be encoded, these bits being referenced d1 to d90. The bits are organized in an array as shown in Figure 1, the array comprising a number k1 of rows and a number k2 of columns, where k1 = 9 and k2 = 10. Product code encoding consists in applying a first block code (known as a row code) to each of the k1 rows so as to obtain additional bits referenced dli (Figure 2) corresponding to encoding each of the k1 rows. By way of example, bits dl1, dl2, and dl3 correspond to encoding the bits d1 to d10. In this case, n2 = 13 represents the total number of columns after the code has been applied and n2 - k2 = 3 represents the number of additional columns due to applying the code. Depending on the block code used, this generates k1*(n2-k2) additional bits. These bits are placed following the bits from which they are derived, thus providing an array having k1 rows and n2 columns.

After this first encoding operation, a second kind of block encoding (referred to as a column encoding) is applied to the n2 columns so as to generate (n1-k1)*n2 additional bits. Thus, in Figure 2, 20 additional bits dci are generated by encoding the k2 columns, and 6 more additional bits dlci are generated by encoding the (n2-k2) columns. In this case the value of n1 is equal to 11

and n1-k1 = 2. By way of example, encoding the data in the first column of the array in Figure 1 gives rise to extra bits dc1 and dc2.

A product code is defined on the basis of the parameters (n1, k1) and (n2, k2) of the row and column codes. The efficiency r of a product code is equal to the product of the efficiencies of the row code and of the column code making it up. I.e. in this case:

$$r = \frac{k1 * k2}{n1 * n2}$$

Another characteristic of a block code is its capacity for correction t. This depends directly on the minimum Hamming distance d_{min} relating to the block code in question.

Specifically:

$$t = \left[\frac{d_{min} - 1}{2}\right]$$

where [x] designates the integer portion of x.

In the state of the art, product codes are used in particular for encoding ATM cells. For short cells of this type, it is necessary to use appropriate encoding; convolutional codes or Reed Solomon codes turn out to be poorly adapted to encoding ATM cells and provide mediocre performance.

French patent application FR 2 769 776 describes a method of encoding a block of data comprising a first zone and a second zone. The method consists in applying a product code to the data block defined as follows:

- a first block code is applied to the first zone of the data block;

- a second block code is applied to the second zone of the data block; and

- a third block code is applied to the data obtained by the first two encoding operations in a direction perpendicular to the first two codes.

With product codes, it is common practice to apply a row code having correction capacity t=1 and to apply a column code having the same correction capacity t=1. This practice has the drawback of obtaining efficiency for the product code that is always greater than 0.5, regardless of the code chosen. Unfortunately, with satellite transmission, in order to obtain a good compromise between the power that needs to be transmitted and the bandwidth that is occupied, it is desirable for code efficiency to come as close as possible to 0.5.

A particular object of the present invention is to devise families of row codes and column codes which make it possible to obtain an encoding rate that is adapted to satellite transmission.

More precisely, one of the objects of the invention is to determine a family of error correcting product codes, and thus of the row codes and the column codes making it up, such that when applied to a short cell they imply a product code efficiency close to 0.5. To select a code compatible with the objects of the invention, it is necessary to satisfy the following conditions:

$$\begin{cases} k1 * k2 \geq I_{cell} & (1) \\ r = \dfrac{k1 * k2}{n1 * n2} \approx 0.5 & (2) \end{cases}$$

where I_{cell} is the number of bits in the cell.

Condition (1) expresses the fact that the product code is applied to blocks of at least cell size, with additional bits, in particular bits referred to in this description below as "padding" bits, and that do not belong to the cell, optionally being added thereto in order to pad it out to the quantity of information required for applying the code. Preferably, it is

desirable to use codes for which the product of the parameters k1 and k2 comes close to the value I_{cell}.

Condition (2) determines that the product of the efficiencies of the row code multiplied by the efficiency of the column code must be close to 0.5 so as to provide encoding that is suitable for satellite transmission.

Preferably, any padding bits added to make up the quantity of information necessary for applying the code are not transmitted. This method amounts to shortening the product code. The decoder knows the non-transmitted sequence that needs to be added in order to decode the sequence of received bits correctly. Under such circumstances, condition (2) is given by:

$$r = \frac{I_{cell}}{n1*n2-(k1*k2-I_{cell})} \approx 0.5 \qquad (2)$$

Furthermore, in order to adapt the efficiency of the code finely, it is possible to avoid transmitting certain redundancy bits, the number omitted being n_{punct}, using a "code puncturing" method applied to the product code. Under such circumstances, condition (2) is given by:

$$r = \frac{I_{cell}}{n1*n2-(k1*k2-I_{cell})-n_{punct}} \approx 0.5 \qquad (2)$$

These objects, and others that appear below, are achieved by a method of encoding a cell made up of bits by means of a product code, given that the cell is presented for coding purposes in the form of an array and that the encoding consists specifically in:

a) applying a first binary linear block code to one dimension of the array (rows or columns) containing the cell; and

b) applying a second binary linear block code to the other dimensions of the array (column or row) containing the cell.

The linear block codes used satisfy the following criterion: one of them has the capacity to correct one error (t=1) and the other has the capacity to correct two errors (t=2).

Advantageously, the binary linear block codes correspond to BCH codes of length n and dimension k, said BCH codes belonging to any one of the following families: (n, k), (n, k-1), (n+1, k), (n-s, k-s), or (n-s, k-1-s) and (n+1-s, k-s), where k, n, and s are integers and where s<k, define the above-mentioned criterion.

Preferably, the method of the invention consists in interlacing the data obtained during step a) prior to step b).

Other characteristics and advantages of the invention will appear on reading the following description of a preferred implementation given by way of non-limiting illustration, and with reference to the accompanying drawings, in which:

- Figures 1 and 2 show the principle of product encoding;
- Figure 3 shows an example of a product code of the invention applied to encoding an ATM cell; and
- Figure 4 shows the efficiency characteristics of a family of BCH codes of the invention.

Figures 1 and 2 are described above with reference to the state of the art.

In a particular implementation of the present invention, the row and column codes used for constructing the product code are (n, k) BCH binary codes, their (n+1, k) extended codes, their (n, k-1) expurgated codes, and the (n-s, k-s), (n-s, k-1-s), and (n+1-s, k-s) shortened codes of these codes, with k, n, and s integers, and with s<k.

The extended codes are obtained by adding a parity bit to each word of a BCH code having an odd minimum Hamming distance. In other words, its generator polynomial g(x) does not contain the factor (x+1). An

expurgated code is obtained from a BCH code having g(x) as its generating polynomial, where g(x) does not contain the factor (x+1). The expurgated code is obtained by the new generator polynomial (x+1)*g(x).

The term BCH code is used below for any of the variants described above.

A pair of codes constituting a product code of the invention comprises the (26,32) extended BCH code whose correction capacity is t=1, and the (21,32) extended BCH code whose correction capacity is t=2. The list of basic BCH codes and of their correction capacities is given at p. 437 of the second edition of the work entitled "Digital communication" by John G. Proakis, published by Mac Graw Hill.

Figure 3 shows an ATM cell (31) comprising 424 bits arranged for encoding purposes in an array of 21 rows by 26 columns for the case where the (32,21) BCH code having t=2 is selected as the row code and the (32,26) BCH code having t=1 is selected as the column code. It is also possible to envisage interchanging the row and column codes. The method whereby the ATM cell is arranged in the array in this case is filling the first row sequentially from left to right, then the second, etc., until all of the bits of the cell have been arranged in the array. In the present case, the first 16 rows are filled completely with bits of the ATM cell, while the 17th cell contains the last 8 bits of the ATM cell. The remaining locations of the array (32) can be filled by optionally random padding bits which need not be transmitted, which amounts to shortening the product code. This method of arrangement has been described because of its simplicity, however it is entirely possible to define some other method of arrangement providing that decoding means are available for distinguishing bits of the ATM cell from any padding bits or puncturing bits, and for reconstituting the ATM cell correctly after decoding.

The efficiency of the product code based on the (32,26) BCH row code and the (32,21) BCH column code is:

$$r = \frac{26 * 21}{32 * 32} = 0.53$$

Figure 4 is made up of Figures 4a, 4b, 4c, 4d, 4e, and 4f and shows the characteristics of pairs of codes making up a product code. These diagram should be considered in pairs (4a, 4b), (4c, 4d), (4e, 4f) where each pair shows the results of simulations for particular families of row and column codes.

In the charts, the X direction represents the shortening value for the row code, and the Y direction of the chart represents the shortening value for the column code. For each combination of a row code and a column code, the direction Z1 in the charts of Figures 4a, 4c, and 4e gives the numbers of code bits generated by the code, while the Z2 direction of charts 4b, 4d, and 4f gives the efficiency of the code.

For the pair (4a, 4b), the row codes and the column codes are derived by shortening the (32,26) BCH code and both have a correction capacity t=1. The efficiencies of the various codes considered in this case extend over the range about 0.55 to about 0.65.

For the pair (4c, 4d), the row codes and the column codes are derived by shortening the (32,21) BCH code and both have a correction capacity t=2. The efficiencies of the various codes considered in this case extend over the range about 0.30 to about 0.45.

For the pair (4e, 4f), the row codes are derived by shortening the (32,26) BCH code and all have a correction capacity t=1, while the column codes are derived by shortening the (32,21) BCH code and all have a correction capacity t=2. The efficiencies of the various codes considered in this case covers the range about 0.45 to about 0.52.

It can be seen from the various charts that for combinations of codes in which one has correction capacity t=1 and the other has correction capacity t=2, i.e. charts 4e and 4f, the conditions (1) and (2) for encoding an ATM cell for satellite transmission are satisfied much better than for codes both having a correction capacity t=1, charts 4a and 4b, or for codes both having a correction capacity t=2, charts 4c and 4d.

CLAIMS

1/ A method of encoding a cell by a product code, said cell being contained in an array whose rows and columns each represent one dimension of said array, the method consisting in:

- applying a first binary linear block code to one dimension of said table;
- applying a second binary linear block code to the other dimension of said array;

said binary linear block codes being represented by their correction capacity;

the method being characterized in that one of said binary linear block codes has the capacity to correct one error while the other of said binary linear block codes has the capacity to correct two errors.

2/ A method according to claim 1, characterized in that said binary linear block codes are BCH block codes or derivatives thereof, one having the capacity to correct one error and the other having the capacity to correct two errors.

3/ A method according to claim 1 or 2, characterized in that said product code applied to said cell has an efficiency close to 0.5.

4/ A method according to any one of claims 1 to 3, characterized in that said cell to be encoded is an ATM cell.

5/ A method according to any one of claims 1 to 4, characterized in that said cell is to be transmitted in a communications system that includes a satellite.

6/ A method according to any one of claims 1 to 5, characterized in that said array containing said cell also contains other bits for padding.

7/ A method according to any one of claims 1 to 5, characterized in that said array containing said cell also contains puncturing bits.

k2

k1										
	d 1	d 2	d 3	d 4	d 5	d 6	d 7	d 8	d 9	d 10
	d 11	d 12	d 13	...						
	d 21	...								
	d 31	...								
k1	d 41	...								
	d 51	...								
	d 61	...								
	d 71	...								
	d 81	...								d90

FIG.1

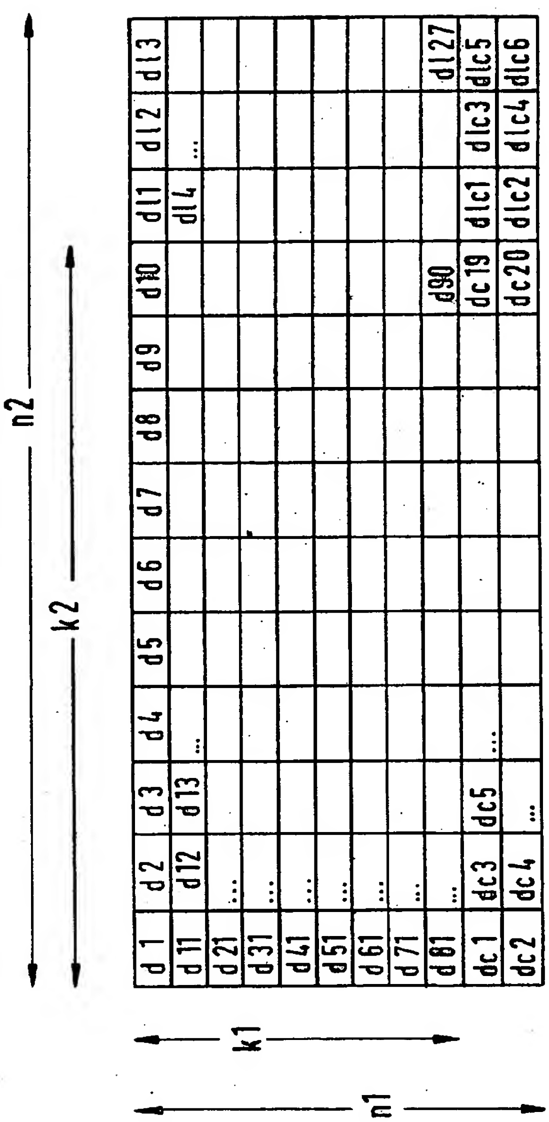

n2
k2
k1
n1
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
dl1
dl2
dl3
d11
d12
d13
dl4
d21
d31
d41
d51
d61
d71
d81
d90
dl27
dc1
dc3
dc5
dc19
dlc1
dlc3
dlc5
dc2
dc4
dc20
dlc2
dlc4
dlc6

FIG.2

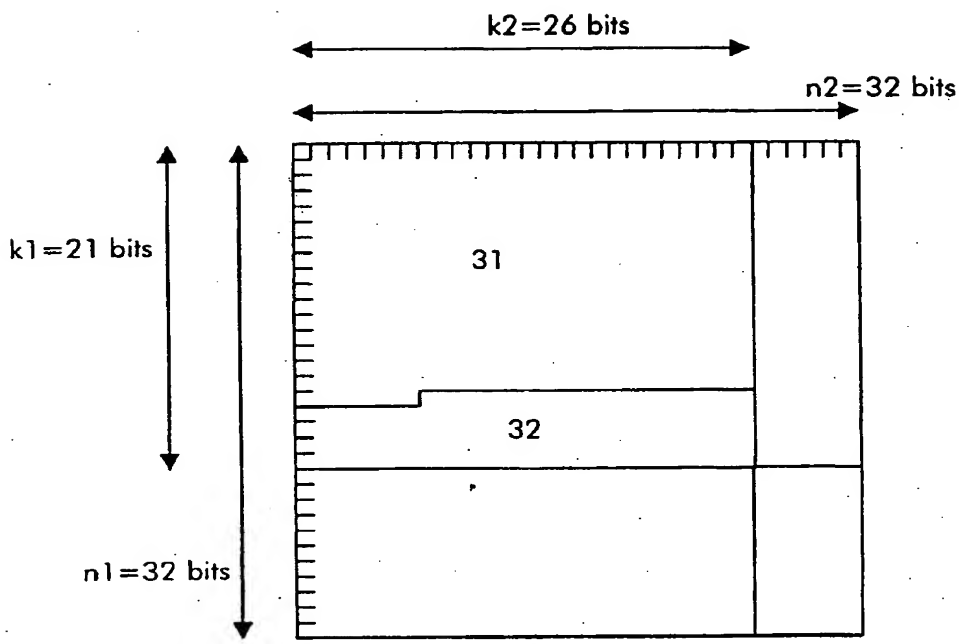


FIG.3

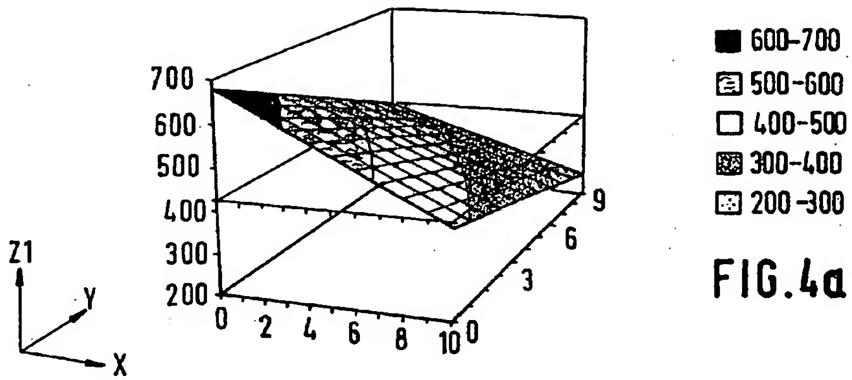


FIG.4a

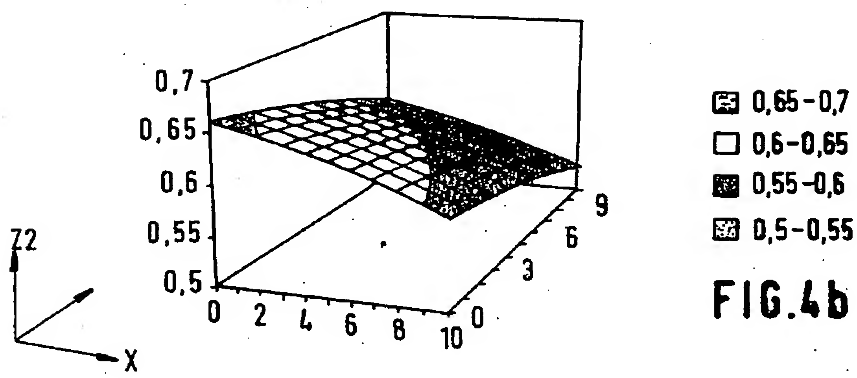


FIG.4b

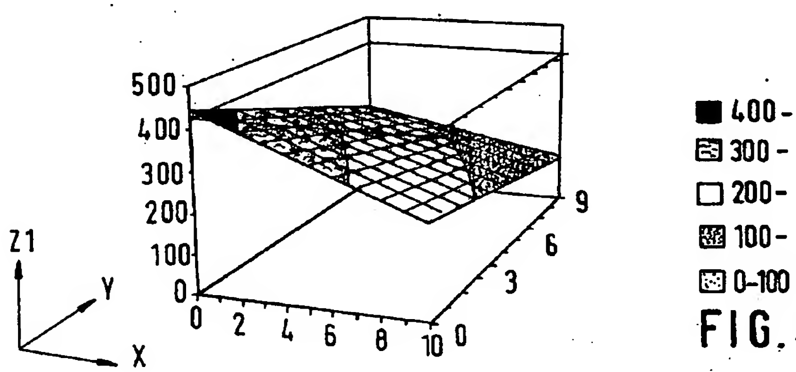


FIG.4c

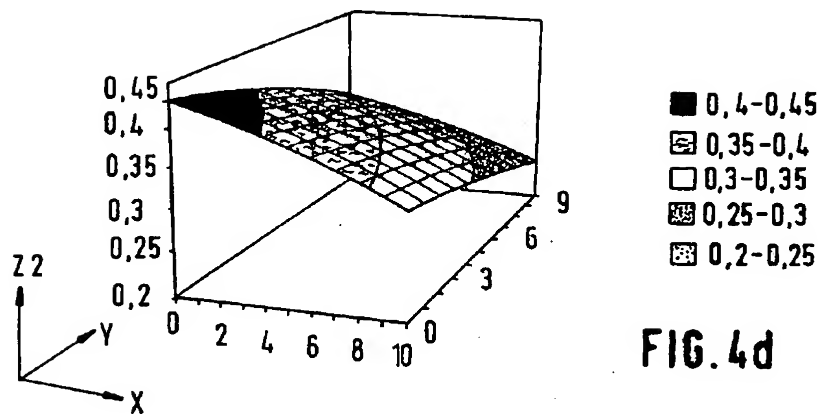


FIG.4d

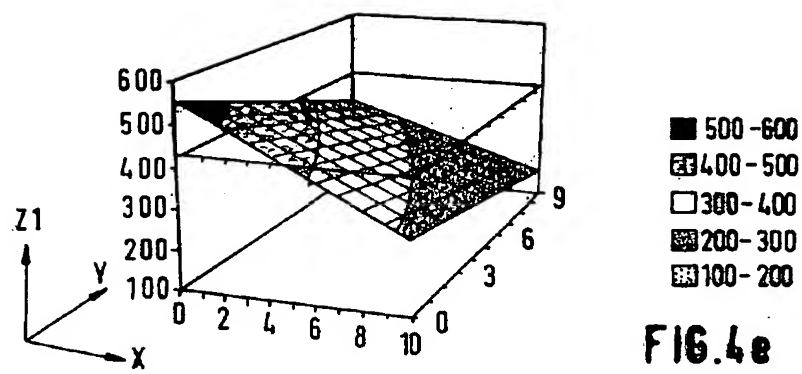


FIG.4e

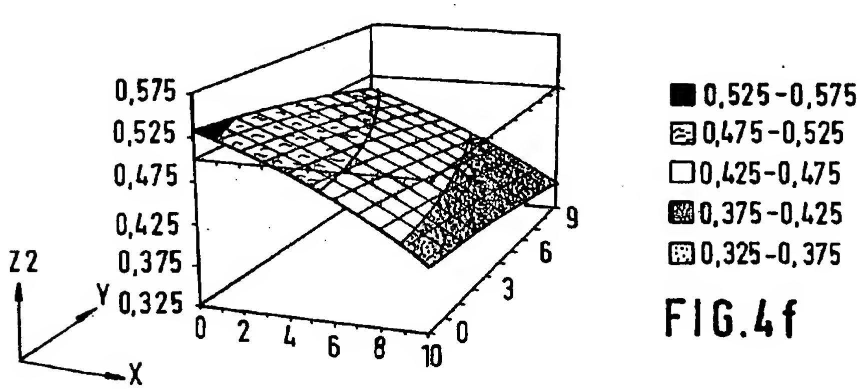


FIG.4f